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Oxygen Consumption of Firefighters During Occupationally Specific Tasks

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Oxygen Consumption of Firefighters During Occupationally Specific Tasks

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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the thesis of

Kelly Brady

submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health Sciences and Human Performance at Ithaca College has been approved.

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ABSTRACT

This study evaluated the physiological costs of specific occupational firefighter (FF) tasks. Subjects were 30 active FF's (>20 hours/month on duty) with a mean age of 34±8.69 years. Measurements including oxygen consumption and heart rate (HR) were recorded while a subject performed occupational tasks designed to simulate the challenges of firefighting. These tasks are typically components of a mandatory, pre-employment physical fitness assessment. Each subject completed two days of testing. Day one included a VO_{2max} test on a treadmill. On day two, HR and oxygen consumption were measured during two FF tasks including a stair climb (SC) and victim rescue (VR). Participants wore a 40-pound weighted vest during the SC and VR tests and National Fire Protection Agency (NFPA) approved jacket, pants, and boots. Maximum oxygen consumption was 41.79±7.82 $ml \cdot kg^{-1} \cdot min^{-1}$, which ranged from 29.50-59.30 $ml \cdot kg^{-1} \cdot min^{-1}$. During the SC and VR tasks, subjects worked at 77.13% and 75.40% of VO_{2max}, respectively. Likewise, HR_{max} was 190.4±2.01 bpm, and varied from 167-207 bpm. Relative HR during SC and VR was 66.36% and 51.50%, respectively. Based on these data, the minimum recommended VO_{2max} for FF to perform these occupational tasks at or below 75% VO_{2max} was 37.16 $ml \cdot kg^{-1} \cdot min^{-1}$. As such, 36.7% of our subjects failed to attain this VO_{2max}. In the best interest of firefighters and public safety, we recommend biannual evaluation to determine VO_{2max} of a FF, and for that to serve as a basis for a safe and effective exercise program. Physical performance testing limited to the onset of hire is not in the best interest of the FF. Both performance testing and regular exercise participation should be a regular and integral part of the FF's job.

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INTRODUCTION

The occupational demands of firefighting require a higher than average level of fitness to perform, while also working at an intensity that poses minimal risk of cardiovascular or musculoskeletal injury. Therefore, to reduce the risk of untoward events, firefighters (FF) should maintain a level of fitness that enables them to safely meet the physical demands of firefighting.

Firefighters are required to perform in many high pressure situations and shifts may last up to 24 hours, with the possibility of dispatch to emergency responses at any time during their shifts or when on-call (Firehire Inc., 2001). Firefighting is an inherently hazardous occupation with a high rate of mortality (Fabio, 2001). According to a recent National Fire Protection Association (NFPA) report (2000), the leading cause of fatalities in FF is stress and over-exertion, often resulting in heart attack. In 1999 alone, there were 112 FF fatalities, with over half of them attributed to stress and over-exertion (IFMA, 2000). These physical demands make appropriate training essential for the safety of the FF, and those whom they serve. The health and well being of firefighters directly affects public safety; therefore, their high-risk profile for cardiovascular (CV) disease should be a national concern (Kay et al., 2000).

Good aerobic fitness, anaerobic power, low body fat and high strength are all required for firefighting. Functional tests are used to determine the ability of a FF to meet the occupational demands of firefighting. They perform many movements that require pushing, pulling, lifting, dragging, climbing, and even hanging. A physically fit FF has a reduced risk for injury or death, and when injured has a faster recovery rate (O'Donoghue, 2002).

All fire departments headed by the International Association of Fire Fighters (IAFF) recognize the need for physical fitness in the firefighting profession and use a physical fitness test that potential candidates must pass to become a FF. Fire departments vary in the physical performance tasks used to screen potential employees; still, they typically require a high level of functional strength. However, it has not been clearly established what the aerobic demand of the FF is during all of the simulated tasks, as well as what percentage of their actual maximum aerobic capacity they are achieving during the tasks.

Due to heavy exercise, compounded by environmental and emotional stress, there is a high level of CV strain on FF; thus, good aerobic fitness should be a prerequisite for firefighting (Byrd & Collins, 1980). The question that is still largely unanswered though is; what is an appropriate CV fitness level for a FF to safely manage heat stress, dynamic muscular work, as well as the load carrying and other demands of firefighting? Moreover, are the tasks of the physical performance tests truly challenging and equivalent to the metabolic demands required of a true fire emergency?

Statement of Purpose

The purpose of this study is to determine the aerobic demands of some typical occupational tasks of FF to more accurately identify a recommended aerobic fitness level for FF. Attainment of the recommended fitness level should help to decrease the risk of injury and myocardial events during firefighting.

Research Questions

The research questions for this study include:

1. What is the maximum oxygen consumption (VO_{2max}) and heart rate of FF?
2. What is the oxygen consumption and heart rate of FF during selected simulated firefighting tasks (i.e., stair climb and victim rescue)?
3. What percentage of maximum oxygen consumption and heart rate are attained by FF during the simulated tasks?
4. What would be a recommended VO_{2max} standard for FF based on the CV demands of the firefighting tasks?

Scope of the Problem

Maximum oxygen consumption is often considered the best indicator of aerobic fitness level or cardiorespiratory capacity. It is the greatest volume of oxygen that the body can utilize during heavy exercise or work. The present study assessed the aerobic demands of some typical occupational tasks of FF to more accurately identify appropriate aerobic fitness level. Attainment of the recommended fitness level should help to decrease the risk of injury and myocardial events during firefighting.

Firefighters, as public service officials, require a higher fitness level to safely perform their duties. The demands of their jobs include, but are not limited to, factors such as high thermal stress, sudden strenuous exercise, and emotional stressors involving life-saving responsibilities of themselves and others. The establishment and maintenance of a minimum value for aerobic capacity is necessary to ensure the safety and effectiveness of FF in the line if duty. The integrity of the entire public service system means finding and setting this requirement as a baseline for FF to remain active in this field. Typically, FF are evaluated on their fitness level once, at the time of application for a position; however, studies are finding evidence suggesting that as FF age, VO_{2max} declines to levels below what may be adequate to perform effectively and safely. A 2002 study by Davis et al. (2002) found an average decrease in VO_{2max} of 15.5 ml, from 54.6 to 29.7 $ml \cdot kg^{-1} \cdot min^{-1}$ as FF age increased from 20 to 50+ years old. These age-related changes observed in this cohort did parallel those of the general population; however, FF need a higher than average VO_2 for their occupation because of the additional stressors discussed above.

Assumptions of the Study

For the purpose of this study, the following assumptions were made at the start of the investigation:

1. The subjects are representative of typical structural firefighters in a small city environment in the U.S.
2. The specific tasks of the Ithaca Fire Department's Physical Performance Assessment represent typical firefighting tasks of fire companies and ultimately represent actual structural firefighting tasks in the field.
3. The subjects supplied honest answers to subjective measures (i.e., rating of perceived exertion (RPE)).
4. The subjects performed each task to the best of their ability, including VO_{2max} test, stair climb and victim rescue.

5. Metabolic measurements using the Sensormedics 2900 metabolic cart (Yorba Linda, CA) and the Cosmed $K4b^2$ (COSMED, Italy) are equally accurate and precise.

Definition of Terms

The following terms are operationally defined for the purpose of this investigation:

1. Aerobic capacity- (also, maximum oxygen consumption, VO_{2max}, or cardiovascular fitness) the maximum volume of oxygen utilized to produce energy during heavy exercise; the ability to deliver and use oxygen under the demands of intensive, prolonged exercises or work.
2. Rating of perceived exertion (RPE)- A subjective impression of overall physical effort, strain and fatigue.
3. NFPA- National Fire Protective Association
4. IAFF- International Alliance of Fire fighters
5. PPA- Physical performance assessment
6. CPAT- Candidate physical ability test
7. IFD- Ithaca Fire Department
8. Tympanic temperature- Body temperature taken in the ear.
9. SCBA- Self-contained breathing apparatus

Delimitations

The delimitations of this study are as follows:

1. Only firefighters from the Ithaca Fire Department were subjects.
2. Only males, aged 18-52 years old served as subjects.

3. A Cosmed K4b^2 (COSMED, Italy) portable VO_2 analyzer was used to measure oxygen consumption and maximum heart rate during the simulated firefighting tasks.

Limitations

The limitations of this study are as follows:

1. For the purpose of this study, and due to limited time and resources, subjects were selected from a sample of convenience. This limits the ability to generalize results to other, more diverse fire departments. Also, those who did not participate may differ from the subjects in the study in ways that could have affected the results.
2. Subjects were all white males, aged 18-52 years, and are active members of the Ithaca Fire Department (IFD). Women were excluded because of the inability to recruit an adequate number, and therefore the results will not reflect potential gender differences.
3. By using humans as subjects, the motivation of the subjects is also a limitation, as well as personal ratings of perceived exertions (RPE). Both are subjective, rather than objective measures and may contribute to individual differences at large.
4. Only two physical performance assessment (PPA) tests were used for this study due to limited time and resources. The measurement variables selected may only indicate performance capabilities on the specific tasks administered and may not be accurate indicators of actual firefighting duties.

LITERATURE REVIEW

Introduction

This chapter reviews the pertinent research related to the purpose of this study. First, the nature of firefighting will be discussed followed by the characteristics of aerobic capacity (VO_{2max}) and the impact, or implications of VO_{2max} on the possible risks (injury, morbidity, and mortality) associated with the physical demands of firefighting.

Physiological Nature of Firefighting

Firefighting is a physically demanding occupation that requires a higher than average level of fitness to perform safely and effectively (Malley et al., 1999). Duties of a FF put extensive physiological strain on the body, particularly the CV system due to the competition for blood flow between active muscles and the skin to maintain thermoregulation of the body. Firefighters are exposed to smoke, toxic chemicals, and must perform their duties in extreme heat while wearing heavy protective equipment (Smith & Petruzzello, 1998). There is an additional emotional stress of saving lives and protecting co-workers. Over time, these situations can negatively affect the overall health and wellness of the FF, and consequently the entire emergency response system. A severe strain is placed upon the aerobic and anaerobic systems (Gledhill & Jamnik, 1992b). Therefore, the physical readiness of a FF is critical for saving civilian lives, and quite possibly his or her own as well (Obermeyer, 1995).

Success of a FF relies on physical readiness and fitness, which is comprised of cardiovascular fitness, endurance, flexibility and muscular strength. Firefighting typically includes tasks such as hanging, lifting and carrying objects up to 80 pounds, pulling or dragging objects up to 135 pounds and working with objects in front of the body of up to about 125 pounds (e.g., weight and water pressure of a charged hose) (Gledhill & Jamnik, 1992a). These tasks must be performed while wearing protective equipment and a self-contained breathing apparatus (SCBA). The protective clothes, equipment and SCBA weigh between 40 and 50 pounds. Firefighters wear this equipment while working an emergency scene and performing strenuous tasks under duress and in a variety of situations (Firehire Inc., 2001). With studies indicating that FF often work at 80-90% of HR_{max} during firefighting activities for prolonged periods (Barnard & Duncan, 1975), it is essential to know what level of fitness is needed to safely and effectively carry out these tasks.

Aerobic Demands and Job-Specific Tasks

Aerobic fitness, or aerobic capacity, of an individual is most commonly described as the oxygen consumption (VO_2) or the greatest volume of oxygen that the body can utilized during strenuous exercise. Maximum oxygen consumption (VO_{2max}) is generally accepted as the best representation of the highest functional limit of the cardiovascular system (Howley, Bassett, & Welch, 1995). This is often the measurement used to determine the overall metabolic cost of physical activity in the field (Howley, Bassett, & Welch, 1995; Hausswirth et al., 1997). It is a common measurement in exercise physiology and interpreted as an index for overall cardiorespiratory fitness (Howley, Bassett, & Welch, 1995). Based on previous research, it is known that FF produce the majority of their energy through aerobic metabolism overall in both hot and thermoneutral conditions (Smith et al., 1997).

O'Connell and colleagues (1986) found that while fully uniformed FF carried equipment up stairs at a rate of 60 steps per minute, heart rates reached between 84-100%

of HR_{max} and oxygen consumption was as high as 63-97% of maximum. In an earlier study, Lemon & Hermiston (1977a) reported that FF attained about 60-80% of VO_{2max} during tests such as ladder raise, ladder climb, victim rescue, and hose drag. This was found despite the absence of the external factors of an emergency scene such as heat, humidity, decreased oxygen, increased carbon dioxide, and emotional stress.

In a later study, the energy cost of stair climbing was measured, and the average VO_2 during the last 30 seconds of ascent was 33.5±4.8 $ml \cdot kg^{-1} \cdot min^{-1}$ and mean HR was 159±15 bpm (83 and 89% of HR_{max}, respectively). This is representative of subjects under normal, everyday stair climbing tasks on average steps; however, does not account for climbing with FF gear and SCBA (Teh & Azziz, 2001). Because absolute VO_2 and body mass index (BMI) are directly associated, (Kales et al., 1999), heavier individuals (higher BMI) would find stair climbing physically more taxing. Therefore, it is likely that a FF wearing turnout gear and a SCBA would attain a higher VO_2 compared to exercise without gear.

When a step test was used to evaluate aerobic capacity while wearing FF gear, a VO_2 of 42.8±8 $ml \cdot kg^{-1} \cdot min^{-1}$ was needed to complete the task. Swank et al. (2000b) reviewed studies that simulated certain FF tasks (e.g. ladder extension, rescues, forcible entry, and hose pulls), and reported that the required VO_2 was between 33.5 and 42 $ml \cdot kg^{-1} \cdot min^{-1}$. It is believed that FF with a VO_{2max} of less than 33.5 $ml \cdot kg^{-1} \cdot min^{-1}$ are unlikely to be able to perform expected work tasks for more than a few minutes at a time (Peate et al., 2002; Swank et al., 2000a).

Sothmann and colleagues (1990, 1992b) recommended that a VO_{2max} of 33.5 $ml \cdot kg^{-1} \cdot min^{-1}$ was an acceptable minimum for FF. They found that individuals with VO_2

$_{max}$ values between 33.5 and 51 $ml \cdot kg^{-1} \cdot min^{-1}$ completed a standard fire suppression protocol more successfully than those with VO_{2max} values of 26-33.49 $ml \cdot kg^{-1} \cdot min^{-1}$. This minimum recommended value of 33.5 $ml \cdot kg^{-1} \cdot min^{-1}$ was designed to displace as few FF as possible from the workforce, and mainly represents a value necessary for fighting a walk-up or low rise fire (Sothmann et al., 1992a; Sothmann et al., 1990; Sothmann et al., 1992b).

Still, Gledhill and Jamnik have recommended a higher VO_{2max} value for FF of 45 $ml \cdot kg^{-1} \cdot min^{-1}$. This was determined to include demands for more intense firefighting tasks as well as allowing sufficient reserve for the FF (Gledhill & Jamnik, 1992b). Despite these minimum recommendations, an investigation of one of the largest fire companies in the United States, a portion of the New York City Fire Department (FDNY) (n=93), revealed that 33% had a VO_{2max} less than 30 $ml \cdot kg^{-1} \cdot min^{-1}$. Other studies of FDNY reported VO_{2max} values ranging from 33-45 $ml \cdot kg^{-1} \cdot min^{-1}$ (Kales & Christiani, 2000). There are however, questions and concerns whether any of these aforementioned values are sufficient. Certainly, attainment of an adequate fitness level should help to decrease the risk of injury and myocardial events during firefighting tasks.

Firefighter Gear Configuration and SCBA

It has been established that firefighting uniforms (turnout gear and SCBA) affect the physiological demands of firefighting. The gear is worn by the FF ultimately to provide burn protection; however, it has a negative impact on the CV system by increasing heart rate, VO_2 and body temperature due to the weight and impermeable material.

The NFPA (NFPA 1500, 1987) has regulated the standard gear configuration to consist of bunker pants with Severus bunker low-rise boots and a Nomex heat resistant hood to protect the head and neck (Smith & Petruzzello, 1998). It also includes Gore-Tex turnout jacket, fire resistant gloves, a helmet and a SCBA. When the standard gear configuration was examined against the hip-boot configuration, the standard gear configuration resulted in longer task completion or performance time, greater thermal strain, and a more enhanced perception of effort and thermal sensation by the FF (Smith & Petruzzello, 1998).

White et al. (1989) studied different gear configurations and found that only the standard gear configuration (turnout gear with SCBA) did not differ in low intensity (shift training and activities) and high intensity (actual fire emergencies) work conditions. The peak HR and RPE, respectively, were 172±9 and 16.4±2.3 for high intensity and 169±9 and 13.0±2.1 for low intensity work. The HR increased at a much faster rate with the standard gear configuration, and never reached steady state, partly due to the low tolerance time for each task. Out of a possible 180-minute test, males lasted 25 minutes and 4 minutes, for the low and high intensity work conditions, respectively. The FF and SCBA configuration tests were stopped when the subject reached 90% of their age-predicted maximum HR. These results show the stressful impact of firefighting gear and SCBA on the ability to maintain work.

In addition to the increases in HR and RPE, skin and rectal temperatures increased compared to work in light clothing and SCBA (SCBA without turnout gear) conditions. This again, re-enforces the fact that the most stressful clothing, including respiratory and protective gear, produced lower tolerance times and, in general, the highest increase in

HR, skin and core temperatures. The data indicate that wearing the typical FF turnout and SCBA poses significant cardiovascular and thermoregulatory stress at all different intensities. This may affect FF efficiency and safety (White et al., 1989). Additionally, in a 1999 study by Malley and colleagues, all FF attained HR_{max} as well as 70-100% of the VO_{2max}, regardless of uniform type. These results are representative of the typical workload expected during firefighting. The rate of change in HR was not significantly affected by uniform type when compared to the control.

Louhevaara et al. (1984) performed studies of FF with SCBA and found that the SCBA adds additional strain to the FF due to its physical attributes, i.e., weight of the respirator and increased resistance to breathing, as well as subjective factors. Ultimately, because of this increased effort of breathing from the increased carbon dioxide (CO_2) concentration in the inspired air and external deadspace of the SCBA, the FF experienced an increase in HR, VO_2, and ventilation. This was found to be true at submaximal and maximal levels; however, an increase in VO_2 and HR were more significant at higher submaximal workloads. Furthermore, Raven and associates (1979) found a decrease in maximum work capacity of 17.5-21% while FF wore SCBA.

The overall metabolic cost of FF tasks ranged from 60-80% VO_{2max}, with significant cardiopulmonary and thermoregulatory strain (Peate et al., 2002). It was found in one particular study that FF had elevated HR prior to even beginning the tasks; suggesting that simply wearing the turnout gear confers a CV strain, in addition to anticipatory effects of the task (Smith et al., 1997). On average, there was also a 20% decrease in maximum work performance, which included decreased maximum work pace and decreased work time to exhaustion (Louhevaara et al., 1995). Louhevaara (1995) also found that regardless of whether an SCBA was worn, there was still an increase in cardiorespiratory and thermal strain at submaximum work levels.

A more recent study by Ftiati and associates (2001) focused mainly on the HR and tympanic temperature changes, as well as body mass (sweat) loss while performing treadmill runs wearing six different fireproof jackets. Wearing the jackets increased HR in each trial, ranging from a maximum of 176 to 187 bpm. Although the highest mean HR was achieved when wearing the leather jacket, there was a significant difference in HR between all of the jackets compared to the control condition (no jacket), in which mean HR_{max} was 161 bpm. Tympanic temperature increased in all trials during exercise bringing about a significantly higher temperature than the control condition. Body mass decrease due to sweat loss was greatest when subjects wore each of the jackets ($p < .05$). This resulted in an increase in CV strain due to reduced plasma volume and stroke volume. This loss implies that the excessively high HR represented a sympathetic nervous system attempt to maintain cardiac output. It is also noteworthy to mention that body mass loss was inversely associated with jacket weight and peak tympanic temperature. These results indicate that firefighting gear, specifically jackets, do impose physiological strain on the body. Heart rate, tympanic temperature, and body mass loss were all significantly greater when wearing gear.

Other investigations of FF and gear configurations found a 76% increase in VO_2 during a 5-minute bout of exercise performed with gear (O'Connell et al., 1986; Petersen et al., 2000). A 35 and 27% increase in VO_2 and HR, respectively, occurred when protective gear was worn (Petersen et al., 2000).

Thermal Stress

The ability of a FF to endure both the physiological and environmental heat strain is primarily reliant on the FF's heat tolerance and VO_{2max} (Gavhed & Holmer, 1989). Studies have been done to assess the CV and heat strain on FF during an actual fire. To perform these evaluations FF were studied primarily during live fire drills.

When overhaul tasks were performed in extreme heat versus a thermoneutral environment, HR increased 37 bpm more during the heat task versus the neutral task. This represents 90% of the age-predicted maximum HR in the hot condition (Smith et al., 1997). With the combination of increased HR and decreased stroke volume (SV) in heat versus thermoneutral environments (Rowell, 1974; Smith et al., 2001), cardiac output (CO) is compromised (Smith et al., 2001). This reduced SV could be from a decrease in venous return (VR), vasodilation in active muscles and skin, decreased plasma volume due to sweating, or a combination of the three (Smith et al., 2001).

Smith and associates (1997) sought to assess thermal stress experienced by FF due to both physical activity and the environment of the FF. There were significant increases in HR, tympanic temperature, blood lactate levels, ratings of perceived exertion (RPE), and state anxiety for both tasks. Expectedly, the increases were more substantial when tasks were performed in the extreme heat versus thermoneutral environment.

Live fire drills were completed to determine the impact on the cardiovascular and psychological responses of FF (Smith et al., 2000). The authors looked at a number of variables including measurements of HR, aortic blood flow, RPE, respiratory and thermal distress, reaction time, and error rate. Significant and ample changes occurred in both physiological and psychological variables in hot, hostile environments. The authors also found a substantial decrease in SV of 30% in heat versus thermoneutral environments (Rowell, 1974; Smith et al., 2000).

Sothmann and associates (1992b) studied HR and oxygen consumption in FF during actual emergency situations. Results indicated that FF worked for an average 15±7 minutes, at 157±8 bpm. This represented approximately 88±6% of their HR_{max}. The average VO_{2max} predicted from the HR x VO_2 calculation was 25.6±8.7 $ml \cdot kg^{-1} \cdot min^{-1}$, or 63±14% of VO_{2max}. The authors stated that the range of 33.5 to 42.0 $ml \cdot kg^{-1} \cdot min^{-1}$ suggested from previous simulation studies for recommended VO_{2max} for FF is sufficient based on the actual data reported. The VO_2 of 25.6 $ml \cdot kg^{-1} \cdot min^{-1}$ observed in this study only represented about 60% of 42 $ml \cdot kg^{-1} \cdot min^{-1}$, leaving sufficient reserve for any unexpected physical tasks that may arise on the scene. The authors did note that structural fire incidents were the only conditions evaluated in this study.

Summary

There are a number of factors that contribute to the demanding nature of firefighting including energy demands, turnout gear configuration, SCBA, thermal stress, and HR response. Firefighters with greater physiological capacity are better prepared to safely endure these conditions, or perform more effectively under these circumstances. However, there is no established minimum requirement for the level of fitness a FF must maintain. Additionally, the physical performance test recruits must pass to become FF are intended to represent the same challenge imposed by an actual live-fire emergency; however, little research has been done to quantify the energy demand, or VO_{2max} of these physical performance assessment tests, or the percentage of VO_{2max} that is attained by the FF. This information is pertinent given the high physical demands of their profession, and will help to identify a requisite level of fitness for FF to reduce the risk of CV event or heat injury.

METHODS

This chapter includes the methods and procedures for this research study. The major sections are subject selection, test procedures, and data analysis.

Subjects

The subjects for this study were 30 male FF who were active members (>20 hours/month on duty) of the fire department in a small city in central New York. The subjects were 34.9±8.69 years old. Subjects were asymptomatic for CV disease and had no more than one risk factor for coronary artery disease, other than age, as described by the American College of Sports Medicine (ACSM, 2006).

All subjects completed a medical/health history questionnaire (Appendix A), and an informed consent (Appendix B) which was approved by the All College Review Board for Human Subjects Research at Ithaca College.

Test Procedures

Subjects reported to the Wellness Clinic at Ithaca College on two separate occasions, for a total of approximately two and a half hours. All sessions took place at Ithaca College in the Wellness Clinic and the exercise physiology laboratory in the Center for Health Sciences.

On the first day of testing subjects completed a maximum graded treadmill test. The test measured resting HR, blood pressure (BP), a 12-lead electrocardiogram (ECG), and maximum oxygen consumption (VO_{2max}). On test day two, subjects completed simulations of stair climb and victim rescue tasks, following a five-minute warm-up on a cycle ergometer.

The maximum exercise test required the subject to jog at a constant, self-selected speed and 0% grade, and the grade was increased 2.5% every two minutes until the subject reached volitional exhaustion or chose to stop the test for any reason. Heart rate, BP, and 12-lead ECG were monitored continuously throughout the test. Expired gases were collected and analyzed to determine oxygen consumption using a SensorMedics 2900 metabolic cart (Yorba Linda, CA). Subjects wore a headgear device to support a two-way breathing valve (Hans Rudolph, Kansas City, MO) to collect expired gases via open circuit spirometry (see Figure 1).

Figure 1. Subject performing VO_{2max} test on day one of the study.

On test day two, two occupationally-specific firefighting tests were completed (stair climb and victim rescue). The protocol began with a 5-minute general body warm-up on a cycle ergometer. The stair climb is a task to simulate climbing stairs in full protective gear while carrying equipment. For this task, the subject wore a 50 pound weighted vest to simulate the weight of the SCBA and high-rise pack. The subject acclimated to the equipment and pace for 20 seconds on the stair climber and immediately continued into three minutes at 60 steps per minute on the manual program of a stepping machine (Tectrix ClimbMax 200, Medway, MA). Stepping resistance was determined by summing body weight and the weight of the vest and fire protective gear. The total time completed, without stopping or touching the handrails more than one time, was recorded. The stair climb event challenges aerobic capacity, lower body musculature, upper body musculature, and balance.

The victim rescue was used to simulate the task of removing a victim or injured partner from a fire scene. For this task, the FF dragged a 185 pound service rescue mannequin 100 feet. The subject approached the mannequin from the head, grasped under the arms and dragged it with only the heels touching the ground for 50 feet in one direction, turned 180 degrees, and dragged it 50 feet back to the start line. The entire victim was dragged across the 50 foot mark to complete the test. The subject was instructed to complete this task as fast as possible. The time, total distance, number of rests, and number of readjustments was recorded. This task challenged aerobic capacity, upper and lower muscular strength and endurance, and anaerobic capacity. Figure 2 shows a subject performing the VR task.

For both of these tasks, the FF wore fire protective gear and a weighted vest to simulate the weight of the SCBA worn when fighting actual structural fires. Both of these protocols mimic the physical performance assessment tests recruits must complete before becoming active FF.

During the stair climb and the victim rescue tests, the FF wore a Cosmed $K4b^2$ portable metabolic system (COSMED, Italy) to measure oxygen consumption via open circuit spirometry. This unit weighs approximately 1 kilogram and was strapped to the back of the FF. Expired gases were collected through a facemask that covers the nose and mouth.

Figure 2. Subject performing victim rescue test on day two of the study.

The Cosmed K4b^2 telemetry system has been shown to be accurate when compared to the Douglas bag method. The Cosmed K4b^2 portable metabolic system is an upgrade of the K4 portable unit, which is the successor of the K2 unit. Both of these units were proven acceptable tools for measurement of oxygen uptake. McLaughlin et al. (2001) found that the K2 measured only expired oxygen concentrations (not including expired carbon dioxide), and was shown to be valid (Crandall et al., 1994; Lucia et al., 1993), reliable (Lucia et al., 1993), and accurate (Crandall et al., 1994) at both submaximal and maximal exercise intensities. When a carbon dioxide (CO_2) sensor was installed in the K2, it was renamed the K4 unit. The Cosmed K4 had been tested against a metabolic cart to assess accuracy for all oxygen uptake measurements from rest to maximum exercise, including VO_{2max}, VCO_{2max}, maximum ventilation, maximum respiratory exchange ratio, and RER_{max}. There were no significant differences between the Cosmed K4 and the metabolic cart for all aforementioned measures (p = 0.68 - 0.91) (Hausswirth et al., 1997).

The $K4b^2$ employs a breath-by-breath gas exchange measurement system. The $K4b^2$, like the K4, has a carbon dioxide and oxygen sensor, allowing both VO_2 and VCO_2 to be measured, yielding an accurate RER (Hausswirth et al., 1997). This allows direct calculation of RER to determine if the subject has reached maximum effort based on RER greater than or equal to 1.10 (ACSM, 2006). Accuracy of the $K4b^2$ unit has been ensured within an airflow range of up to 20 $l \cdot sec^{-1}$ with accurate measurements of ventilation ranging between zero and 300 $l \cdot min^{-1}$ ($K4b^2$ manual). The $K4b^2$ has been directly tested against the criterion Douglas bag method, and was deemed an acceptable device and a useful tool in determining energy cost of many sport and real life activities. Some significant differences were found between the $K4b^2$ and the criterion Douglas bags; however, the magnitudes of those differences were small, all less than 100 $ml \cdot min^{-1}$

during exercise. These values are physiologically insignificant for most purposes (McLaughlin et al., 2001).

With the use of the $K4b^2$ telemetry unit, the actual VO_2 of FF during occupational tasks was measured rather than estimated or predicted, as in most previous studies. Previous research typically reported HR, temperature, blood flow, as well as psychological variables. This measurement device more accurately determined the aerobic demand associated with firefighting duties compared to prediction of VO_2 from HR or workload.

Data Analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) statistical software. Descriptive statistics were calculated for all variables. Independent variables included age and individual test protocols (VO_{2max}, stair climb, and victim rescue). Dependent variables included VO_2 and HR values from the treadmill as well as the two occupational tasks (stair climb and victim rescue).

Peak HR was determined as the mean of the final three HR's for the stair climb and victim rescue tasks for each FF. The same was also done for peak VO_2 achieved during the two occupational tasks.

One sample t-intervals were performed to determine the 95% confidence intervals for the two occupational tasks and the maximum treadmill test. Regression analyses were performed to determine if peak heart rate and/or peak VO_2 from either occupational task could predict VO_{2max}. The percentage of peak HR and peak VO_2 were also calculated to determine exercise intensity during the two occupational tasks.

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RESEARCH MANUSCRIPT

INTRODUCTION

The occupational demands of firefighting require a higher than average level of fitness to perform and work at an intensity that poses minimal risk of cardiovascular or musculoskeletal injury. Therefore, to reduce the risk of untoward events, firefighters (FF) should maintain a level of fitness that enables them to safely meet the physical demands of firefighting.

Firefighters perform strenuous physical work in heavy protective gear and often under environmental extremes. They undergo excessive physiological strain contributed to by several factors, including but not limited to, (a) radiant heat from fire, (b) metabolic heat produced by working muscles, and (c) the heavy, insulative, protective gear that traps metabolic heat. According to the most recent National Fire Protection Association report (2000), the leading cause of fatalities in FF is stress and overexertion, of which many result in heart attacks. In 2005 alone, there were 115 FF fatalities, with over half (62) attributed to stress and overexertion, and 55 specifically from heart attacks (USFA, 2006).

Good aerobic fitness, anaerobic power, low body fat and high strength are all required for firefighting (McTrusty & O'Donoghue, 2002). Functional tests are used to determine the ability of a FF to meet the occupational demands of firefighting. They perform many movements that require pushing, pulling, lifting, dragging, climbing, and even hanging. A physically fit FF has a reduced risk for injury or death, and when injured has a faster recovery rate (Obermeyer, 1995).

Fire departments headed by the International Association of Fire Fighters (IAFF) recognize the need for physical fitness in the firefighting profession and use a physical fitness test that candidates must pass to become a FF. Fire departments vary in the physical performance tasks used to screen potential employees; still, they typically require a high level of functional strength. However, it has not been clearly established what the aerobic demand of the simulated tasks, as well as what percentage of maximum aerobic capacity is achieved during the tasks.

Due to heavy exercise, compounded by environmental and emotional stress, there is a high level of cardiovascular (CV) strain on FF; thus, good aerobic fitness should be a prerequisite for firefighting (Byrd & Collins, 1980). The question that is still largely unanswered though is; what is an appropriate CV fitness level for a FF to safely manage heat stress, dynamic muscular work, as well as load carrying and other demands of firefighting? Therefore, the purpose of this study was to determine the metabolic demands of some typical occupational tasks of FF to more accurately identify an appropriate fitness level for FF.

METHODS

Subjects

Thirty apparently healthy male firefighters (19-52 yrs) were recruited from a local fire department in a small city in central New York State. Prior to testing, all subjects provided written informed consent. The testing protocol was approved by the All College Review Board for Human Subjects Research at Ithaca College in Ithaca, NY. Subjects completed two days of testing for this study. Table 1 presents descriptive characteristics of the subjects.

Table 1: *Mean age, height and weight of firefighters (N=30).*

	Age (yrs)	Height (m)	Weight (kg)
Mean	34.93	1.79	91.03
SD	8.69	0.05	12.29
Range	18-52	1.68-1.88	72.00-116.00

Test Protocol

Data were collected over two days. On day one, subjects completed a maximum graded exercise test. On day two, subjects performed two occupationally-specific work tasks. Test days were separated by at least one week and no more than 60 days.

VO_{2max} Test

On day one, subjects completed a maximum graded treadmill test. Subjects ran at a self-selected speed, and grade increased by 2.5% from 0% every two minutes until volitional exhaustion was reached. Heart rate, blood pressure (BP), RPE, 12-lead ECG, and oxygen consumption (VO_2) were measured during each stage throughout the test. Expired gases were collected and analyzed to determine oxygen consumption using a SensorMedics 2900 metabolic cart (Yorba Linda, CA). Subjects wore a headgear device to support a two-way breathing valve to collect expired gases via open circuit spirometry. Subjects were instructed to exercise to volitional exhaustion but were free to stop the test for any reason. Criteria used to determine if the subject gave a maximum effort included; $HR_{max} \geq \pm$ 10 bpm of age-predicted HR_{max}, respiratory exchange ratio (RER) ≥ 1.1, leveling off or plateau of VO_2 with an increase in workload. The first two criteria were met by all subjects. The average RPE was 16.4, which is also representative of a maximal effort on the BORG 6-20 scale.

Occupationally-Specific Tasks

On day two, subjects performed two occupationally-specific tasks that included a stair climb (SC) and victim rescue (VR). The SC test was performed on a Cybex Tectrix ClimbMax 200 step ergometer (Medway, MA) while wearing full protective gear and a 50 pound weighted vest to simulate the weight of the self-contained breathing apparatus (SCBA) and high-rise pack. The subject acclimated to the stair climber for 20 seconds and immediately commenced a 3 minute test at 60 steps per minute on the manual program of the step ergometer. Step resistance was calculated as the sum of body weight and weight of the vest and fire protective gear. Upon completing the SC test, the subject immediately commenced the VR test. The VR test simulated removing a victim or injured partner from a fire scene. For this task, the FF dragged a 185 pound service rescue mannequin 100 feet. The subject approached the mannequin from the head, grasped under the arms and dragged it with only the heels touching the ground for 50 feet in one direction, turned 180 degrees, and dragged it 50 feet back to the start line. The entire victim was dragged across the 50-foot mark to complete the test. The FF's were asked to perform the task as fast as possible. Both of the aforementioned protocols mimic portions of the physical performance assessment tests that recruits must complete before becoming an active FF.

Measurements

During both the SC and the VR tests, the FF wore a Cosmed K4b^2 portable metabolic system (COSMED, Italy) to measure VO_2 via open circuit spirometry. This unit weighs approximately 1 kilogram and was strapped to the back of the FF. Expired gases were collected through a facemask that covers the nose and mouth. Peak heart rate and VO_2 were measured for both tasks. During the VR test, performance time, total distance, and number of rests were recorded.

Statistical Analysis

One sample t-intervals were completed to determine the 95% confidence intervals for VO_2 and HR for the SC and VR. Regression analysis was performed to determine if peak heart rate from VR or SC could predict either maximum heart rate or maximum oxygen consumption. The percentage of peak heart rate and peak oxygen consumption were also calculated to determine exercise intensity during the two occupational tasks.

RESULTS

Physiological Measures

Mean, standard deviation (SD), and a 95% confidence interval for the physiological data obtained during the two days of testing are presented in Table 2.

Table 2: *Summary of mean VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) and mean HR (bpm) during maximum treadmill (TM), stair climb (SC), and victim rescue (VR) tests (N=30).*

	Mean	SD	95% CI	
			Lower	Upper
HR-VR	143.3	16.94	136.94	149.59
HR-SC	146.6	13.30	141.64	151.58
max HR-TM	**190.4**	**10.99**	**186.33**	**194.54**
VO_2-VR	20.98	4.45	19.32	22.65
VO_2-SC	26.96	2.45	26.04	27.87
max VO_2-TM	**41.79**	**7.82**	**38.87**	**44.71**

Table 3 includes mean relative VO_2 and HR attained during the maximum treadmill test, the VR and SC tests. Relative (%) values were calculated for the SC and VR tests by dividing HR and VO_2 during the tests by the respective values from the maximum treadmill test.

Table 3: *Mean %VO_{2max} and mean HR_{max} during stair climb (SC) and victim rescue (VR).*

	SC	VR
HR (%)	77.1	75.4
VO_2 (%)	66.4	51.5

Heart Rate

The mean HR_{max} during the treadmill test was 190.4 bpm, with a 95% confidence interval of 186.33 to 194.54. The mean HR achieved during the stair climb test was 146.6 bpm (95% CI=141.64-151.58), which was 77.13% of HR_{max}. The HR achieved during the VR test was 143.3 bpm (95% CI=136.94-149.59), which was 75.40% of the HR_{max}.

Regression analyses indicated that peak heart rate from the SC ($p = 0.135$, $r^2 = 0.078$) and VR ($p = 0.181$, $r^2 = 0.063$) could not predict HR_{max}. Likewise, HR for the VR did not predict VO_{2max} ($p = 0.574$, $r^2 = 0.011$). However, peak HR during the SC contributed significantly to the prediction of VO_{2max} ($p = 0.043$, $r^2 = 0.139$), but accounted for only 13.9% of the variance in VO_{2max}.

Oxygen Consumption

As shown in Table 2, VO_{2max} from the treadmill test was 41.79 $ml \cdot kg^{-1} \cdot min^{-1}$ (95% CI=38.87-44.71). During the SC test, VO_2 was 26.96 $ml \cdot kg^{-1} \cdot min^{-1}$, which was 66.36% of VO_{2max}. During the VR test, VO_2 was 20.98 $ml \cdot kg^{-1} \cdot min^{-1}$, and indicated that subjects worked at a lower relative VO_2 of 51.50% of VO_{2max} compared to the SC test. However, it is important to note that the VR test was very short in duration, averaging 26.90 seconds, with a range of 17.52-43.90 seconds, and did not represent a good aerobic challenge.

DISCUSSION

The physical demands of firefighting are substantial. Together with the thermoregulatory challenge imposed by fire protective gear and work in hot environments, the cardiovascular challenge to the FF exceeds that of most individuals. Pre-employment screening for the occupational demands of fire fighting is designed to assess the physical preparedness as well as risk associated with firefighting.

Efforts to determine the minimum aerobic capacity required of a FF suggest that a VO_{2max} less than 33.5 $ml \cdot kg^{-1} \cdot min^{-1}$ is not sufficient to perform expected work tasks for more than a few minutes at a time (Peate et al., 2002; Swank et al., 2000b). Sothmann and colleagues (1990, 1992b) also recommended that a VO_{2max} of 33.5 $ml \cdot kg^{-1} \cdot min^{-1}$ is an acceptable minimum for FF. They found that those with a VO_{2max} between 33.5-51 $ml \cdot kg^{-1} \cdot min^{-1}$ completed a standard fire suppression protocol more successfully than those with VO_{2max} values of 26-33.49 $ml \cdot kg^{-1} \cdot min^{-1}$. Still, Gledhill and Jamnik (1992b) recommend a higher VO_{2max} of 45 $ml \cdot kg^{-1} \cdot min^{-1}$. This was determined to include demands for more intense firefighting tasks and allow for sufficient reserve.

Subjects in the present study were firefighters with an average VO_{2max} of 41.79±7.82 $ml \cdot kg^{-1} \cdot min^{-1}$, which ranged from 29.50-59.30 $ml \cdot kg^{-1} \cdot min^{-1}$. During the two occupational tasks performed for this study (SC, VR), subjects worked on average, at 77.13% and 75.40% of VO_{2max}, respectively. Likewise, HR_{max} for these subjects were 190.4±2.01 bpm, and varied from 167-207 bpm. Relative HR during SC and VR were 66.36% and 51.50%, respectively. The relative VO_2 and HR response during firefighting tasks appear to be below or comparable to typical guidelines for exercise prescription of

50-85% VO_{2max} or 77-90% HR_{max} for an average person, based on ACSM guidelines (ACSM, 2006). Thus, it is questionable as to whether or not these tasks are challenging enough to distinguish job preparedness and risk level of firefighters.

The physical and physiological demands of firefighting are constant and independent of age and fitness level. Considering the above ACSM recommendations for exercise intensity based on a duration of 20-30 minutes, VO_2 and HR data were reported at a CI=95% to account for the greater physiological demands of firefighting compared to an average, healthy person. For example, HR for the upper 95% CI was 151 bpm. A firefighter with an exercise HR of 151 bpm, working within the recommended intensity range of 77-90%, would need to have a maximum HR of 168 bpm (90%) to 196 bpm (77%).

Using data from the 3 minute SC test, Table 4 was constructed to identify the percentage of FF's from the present study who do not have a large enough VO_{2max} to complete the SC test within the ACSM recommended exercise intensity range for VO_2 and HR.

Table 4 includes the predicted relative (%) VO_2 and HR based on the upper limit of the 95% CI. For a predicted relative VO_2 of 85%, 6.7% of the subjects failed to achieve a sufficient VO_{2max} of 32.79 $ml \cdot kg^{-1} \cdot min^{-1}$ to exercise or perform firefighting duties at this intensity, and actually worked harder than the recommended maximum intensity for the SC test. As expected, most FF's (96.7%) worked at or above 50% VO_{2max} for this test.

Table 4: *Summary of ACSM recommended exercise intensity ranges for relative VO_2 (50-85%) and HR (75-90%), and the percentages of firefighters from this sample who worked above those intensities during the SC test.*

	VO_{2max}	HR_{max}	% FF with VO_2 above designated intensity during SC test	% FF with HR above designated intensity during SC test
90%	N/A	168.42	N/A	0.03
85%	32.79	178.33	6.7	20.00
75%	37.16	202.11	36.7	90.00
65%	42.88	N/A	60.0	N/A
55%	50.67	N/A	83.3	N/A
50%	55.74	N/A	96.7	N/A

According to the ACSM guidelines (ACSM, 2006), a physically fit individual should be able to work at 75% of maximum aerobic capacity, for extended periods of time (at least 20 minutes at a time). A firefighter, especially a career FF, should be able to withstand this level of activity, including the addition of the physical and emotional distress that accompanies firefighting activities. This intensity would account for sufficient reserve needed for other factors not included in this study such as thermal and emotional stress, and extended physical distress. Based on this study, the minimum recommended VO_{2max} level a FF should have to safely perform duties with decreased risk for cardiovascular injury and/or death is 37.16 $ml \cdot kg^{-1} \cdot min^{-1}$(or 75% VO_{2max}). According to our calculations, 36.7% of the FF's in this sample were not at a fitness level to safely perform the tasks at an emergency scene, or for a prolonged period.

A comparison of this study group to a sample of 520 non-Hispanic males (Sanders & Duncan, 2006) of similar age (34.6±0.5 years) revealed that the aerobic capacity of our subjects was 6% lower (41.8 vs. 44.5 $ml \cdot kg^{-1} \cdot min^{-1}$). In addition, two-thirds of the firefighters in this study were below the mean VO_{2max} of 44.5 $ml \cdot kg^{-1} \cdot min^{-1}$ for the average American white male (Sanders & Duncan, 2006). While the range of ages of FF's in the present study is greater than the two comparison groups, it is important to remember that the physical demands of firefighting remain the same, regardless of age or gender.

Additionally, according to the ACSM guidelines (ACSM, 2006), a physically fit individual should be able to work under 85% of HR_{max}. Table 4 shows that 20% of the firefighters were above 85% of mean HR_{max}, with 90% above 75% of mean HR_{max}. With 90% of the subjects approaching the recommended upper intensity limit of 85% of HR_{max}, it is suggested that firefighters maintain a minimum level of fitness to safely perform firefighting duties. Monitoring heart rate is a more practical indicator of effort due to ease of measure in the field. This is another way to assess the safety of a firefighter's ability to safely accomplish occupational tasks.

In summary, these data indicate a minimum VO_{2max} for firefighters of 37.16 $ml \cdot kg^{-1} \cdot min^{-1}$ to account for physical demands of firefighting, thermal stress, emotional stress, and sufficient reserve to safely perform and endure a fire challenge. Based on these results, a substantial minority of firefighters in this study (36.7%) failed to achieve the minimum aerobic capacity and could be considered at greater risk for a cardiovascular event associated with their job performance.

Summary and Future Recommendations

Firefighters in this study serve 32.4 square miles, which is roughly 40,600 residents, plus students and commuters. Sometimes the daily population within their call district swells to 100,000+ people. It is important to ensure their safety, as best as possible, through sufficient physical preparedness to meet the demands of their job. With approximately 4200+ calls per year, it is pertinent that the information from this study is taken seriously, and implemented.

This study was limited in several ways that should be considered in future research. First, the physical performance assessment (PPA) test that FF's must complete successfully to be hired typically consists of eight tasks performed in succession. In contrast, only two isolated tasks were performed for the present study. Given that 7% exceeded the recommended intensity based on VO_2 and 20% exceeded based on HR, it is likely that a greater percentage of FF's would do so when performing eight successive tasks as quickly as possible.

Second, our test protocol did not fully represent the thermal stress that is typical at a fire scene. Although the FF's wore protective gear during the SC and VR tests, they did not wear it during the maximum treadmill test, nor did they exercise in a hot environment. Consequently, the magnitude of cardiovascular drift (CV) that would typically challenge a FF during a live fire challenge was not present in this study.

Cardiovascular drift is an increase in HR to maintain an adequate cardiac output (CO) to complete the given exercise task or workload. Cardiovascular drift can occur in thermoneutral environments or when exposed to prolonged periods of exercise or heat. Warmer environments generally result in greater changes. Wingo and associates (2005) found that cyclists who exercised between 15 and 45 minutes increased HR 12%, decreased stroke volume (SV) 16%, and decreased VO_{2max} 19%. Submaximal VO_2 increased slightly over time, but the $\%VO_{2max}$ the subjects worked at ranged from 63±5% at 15 minutes to 78±8% at 45 minutes. These results illustrate the CV stress imposed by prolonged exercise in a hot environment. The increased metabolic demand (CV drift) must be considered when determining a safe minimum VO_{2max} requirement for FF's. Heat stress from the environment and thermal protective gear increased sweating, and this, paired with decreased ability to thermoregulate the body due to gear configurations, increases the possibility and severity of CV drift. Because the SC and VR tests did not account for this external heat exposure, the increase in internal body temperature may not be fully represented during the short duration of the tests; thus, the data from this study may be a low estimate of minimum VO_{2max}.

Another limitation of this study is the length of work time. The longer duration of the SC test was only three minutes. Generally, FF's work at a fire scene until the oxygen tank runs out, which is about 30 minutes. Firefighters resume their duties fighting the fire after a change of tanks. Typically, subjects in this study fight actual fires during 6% of their calls, and most last for less than 20 minutes. Still, they are expected to maintain a fitness level that will allow them to work for that long, or longer, if necessary.

Considering the limitations of our study, and our conservative recommendation of a minimum VO_{2max} of 37.16 $ml \cdot kg^{-1} \cdot min^{-1}$, 36.7% of our subjects failed to reach this standard. In comparison to previous studies, our recommended VO_{2max} is higher, but still conservative for reasons stated above. In 2001, 40% of the deaths of FFs were due to heart attacks, all attributed to stress or overexertion. This accounts for the largest portion of deaths for FF's that year (LeBlanc & Fahy, 2002). And as mentioned previously, 62 deaths (53.9%) were attributed to stress and overexertion in 2005, with 55 of them from heart attacks alone. This again represents the largest portion of deaths for FFs that year (USFA, 2006).

In the best interest of firefighters and public safety, we recommend testing every other year to determine VO_{2max} of a firefighter and for that to serve as a basis for a safe and effective exercise program. Physical performance testing limited to the onset of hire is not in the best interest of the FF. Both performance testing and regular exercise participation should be a regular and integral part of the firefighter's job.

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APPENDIX A

Medical History and Health Habit Questionnaire

Name: ______________________________

Age: _____

Birthdate: __________

Height: _____ inches

Weight: _____ pounds

What activities do you currently participate in?

1. ____________________
2. ____________________
3. ____________________

Work Address: __________________________________ Phone: __________________

Home Address: __________________________________ Phone: __________________

Present Physician: ________________________________

Family History: Check if any blood relatives (parents, siblings, etc.) have/had:

- ❑ Heart Disease
- ❑ Stroke
- ❑ Diabetes
- ❑ High Blood Pressure
- ❑ High Cholesterol
- ❑ Other
  Please explain ____

APPENDIX A (continued)

Medical/Health History: Check if you have/had:

- ❑ Heart Disease/Stroke
- ❑ High Blood Pressure
- ❑ Heart Murmur
- ❑ Skipped, rapid beats, or irregular rhythms
- ❑ Rheumatic Fever
- ❑ Cancer
- ❑ Lung Disease
- ❑ Diabetes
- ❑ High Cholesterol
- ❑ Epilepsy
- ❑ Injuries to back, knees, or ankles
- ❑ Other

Please explain ______________________________

Present Symptoms: Have you recently had:

- ❑ Chest Pain
- ❑ Shortness of Breath
- ❑ Lightheadedness
- ❑ Heart Palpitations
- ❑ Loss of Consciousness
- ❑ Illness, surgery, or hospitalization
- ❑ Ankle/Leg swelling
- ❑ Joint/Muscle Pain
- ❑ Allergies (if yes, please list under other)
- ❑ Other

Please explain ______________________________

Please indicate if you currently have been diagnosed with cardiovascular, pulmonary, or metabolic disease (ex. Diabetes). These diseases may exclude you from participation in the program.

- ❑ Cardiovascular Disease
- ❑ Pulmonary Disease
- ❑ Metabolic Disease

List all medications currently taking:

1. ____________________

2. ____________________

3. ____________________

APPENDIX A (continued)

Health Habits:

1. Smoking History:

    Do you smoke?

    - ☐ yes
    - ☐ quit
    - ☐ never

    What did (do) you smoke?

    - ☐ cigarettes
    - ☐ cigars
    - ☐ pipe

    How much did (do) you smoke a day? _____

    How long have you been smoking? _____

    If you've quit, when? _____

2. Exercise Habits:

    Do you presently engage in physical activity?

    - ☐ yes
    - ☐ no

    What kind of activity? ____

    How hard?

    - ☐ light
    - ☐ moderate
    - ☐ heavy

    Did your past exercise habits differ from what you are doing now?

    - ☐ yes
    - ☐ no

    What kind of exercise did you do in the past? ____________________________

    How hard?

    - ☐ light
    - ☐ moderate
    - ☐ heavy

    Is your occupation:

    - ☐ sedentary
    - ☐ active
    - ☐ heavy work

    Explain your occupation ____

    Do you have discomfort, shortness of breath, or pain with exercise?

    - ☐ yes
    - ☐ no

    If yes, what type of exercise? ____

APPENDIX A (continued)

3. Nutritional Behavior:

Do you consider yourself to be overweight?

ق yes
ق no

How long have you been overweight? __________

How many meals do you typically eat per day? _____

How often do you eat outside of the home? ____/week

Do you presently consume alcohol?

ق yes
ق no

If yes, what do you drink? ____________________number of drinks/week _____

4. Stress:

Do you consider your day stressful?

ق yes
ق no

What is the nature of your stress? ______________________________________

How many hours do you sleep typically? _____ hours

Is your sleep sound?

ق yes
ق no

Goals for the Program:

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Signature: ____ Date: _______________

APPENDIX B

Oxygen Consumption of Firefighters During Occupationally Specific Tasks
INFORMED CONSENT DOCUMENT

1. **Purpose of the Study**
   The primary purpose of this study is to determine the aerobic demands of some typical occupational tasks of fire fighters to more accurately identify an aerobic fitness level for fire fighting.

2. **Benefits of the Study**
   The results of the study will add to the current body of knowledge regarding the occupational demands of fire fighters as well as help determine a baseline aerobic capacity that is needed for fire fighters to perform their duties effectively and safely.

3. **Your participation Requirements**
   You will be asked to report to the Wellness Clinic evaluation room at Ithaca College on two separate occasions (approximately 2.5 hours total). You will complete a health history, informed consent, and 24- hour history questionnaire. On the first day, resting heart rate, blood pressure, and ECG will be measured to assess cardiovascular function. You will then perform an exercise test on a motor-driven treadmill or a cycle ergometer. The exercise intensity will begin at a level you can easily maintain and will be advanced in stages depending on your fitness level. We may stop the test at any time because of signs of fatigue or you may stop when you wish because of personal feelings of fatigue or discomfort. We will monitor your heart rate, blood pressure, ECG, and oxygen consumption throughout the duration of the test. On day 2 you will perform various tests to help assess your overall fitness level. The sit and reach test will be used to determine flexibility. You will sit on the floor with your legs extended in front of you. You will place your heels against the sit and reach box, about 10-12 inches apart, legs fully extended. You will slowly reach forward, as demonstrated during the test, and the best of three measurements will be recorded. Muscular fitness will be determined with a grip dynamometer and push-up and curl-up (crunch) tests. For the grip strength test you will hold the grip dynamometer in one hand and squeeze as hard as possible, with the better of two trials recorded for each arm. When performing the push- up test, you will perform as many standard push- ups as you are able to do. You are required to lower your body to the mat, and maintain proper form (back straight, hands shoulder width apart, head up). The total number you perform consecutively without rest is counted as your score. For the sit- up test you will lie face up with knees at a 90-degree bend and hands placed behind head or across the chest. You will then be timed for one minute to see how many times you can successfully perform a sit- up, which involves touching your elbows to your knees. Body composition will be measured at seven standard sites on your body with calipers. Pulmonary function will be measured with a spirometer to determine your lung function based on age, gender, and height. The occupational tasks will be performed last. The ladder lift requires you to remove a 14- foot roof ladder from an overhead bracket, which will be placed at a height similar to the height of the brackets on a fire truck. You will place the ladder on the ground, release your handgrip and stand upright. You will then lift and return the ladder to the brackets. The task will be timed for 30 seconds, and the number of successful trials completed will be recorded. During the hose carry, you will pick up a "Humat" hydrant assist valve with attached 50- feet of 5- inch supply hose dragging behind and carry it 60 feet. The task will be timed. For both of these tasks, you will wear their fire- protective gear and a weighted vest to simulate the weight of the self- contained breathing apparatus (SCBA) worn when fighting actual fires. Both of these protocols mimic the physical performance assessment tests you must complete before becoming a fire fighter. During the last two functional tests mentioned, you will wear a portable metabolic system to measure oxygen consumption. This unit weighs approximately 1 kilogram and is strapped to the chest or back. You will breathe through a facemask that covers the nose and mouth so that expired gases may be collected.

____
Initial here

APPENDIX B (continued)

4. **Risks of Participation**
Testing for muscular strength and endurance, flexibility, body composition and pulmonary function are all non- invasive and involve only a small risk of muscle soreness or injury. The maximal exercise cycle or treadmill test and the occupational tests, i.e. the ladder lift and hose carry, may pose some risk for delayed onset muscle soreness and/ or injury. Both tests will be performed to maximum; however, warming- up prior to testing will minimize your risk of injury. There is a small risk of a myocardial event or death associated with the maximum cycle/ treadmill test. All involved with this testing will follow the guidelines for exercise testing published by the American College of Sports Medicine (2), to minimize the risk of untoward events.

In the event of an emergency, first aid and/ or CPR will be administered as necessary by the certified investigator, Campus Safety will be summoned (x43333) and/ or a physician as needed (x43177). For any non- emergent medical concerns, you will be referred to the Health Center.

5. **If You Would Like More Information about the Study**
If you have any questions or comments about the study, feel free to contact Kelly Brady at the Wellness Clinic (274-1301), or Betsy Keller at 274- 1683.

6. **Withdrawal from the study**
You are free to withdraw from participation from this study at any time.

7. **Confidentiality**
All data collected in this study will be number coded to insure confidentiality of your results. Subject names will not appear in any reports resulting from this study. Data will be presented in a group format.

I have read and understand the above document. I agree to participate in this study and realize that I can withdraw at any time. I also understand that I can and should address questions related to this study at any time to the researcher involved. I also verify that I am 18 years or older.

____
Name of Subject (type or print)

____________________________ ________________________
Signature of Subject Date

APPENDIX C

INFORMED CONSENT FOR A GRADED EXERCISE TEST

Adapted from ACSM

1. Explanation of the test

You will perform an exercise test on a motor-driven treadmill or a cycle ergometer. The exercise intensity will begin at a level you can easily maintain and will be advanced in stages depending on your fitness level. We may stop the test at any time because of signs of fatigue or you may stop when you wish because of personal feelings of fatigue or discomfort. We will monitor your heart rate, blood pressure, ECG, and oxygen consumption throughout the duration of the test.

2. Risks and Discomforts

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, disorder or heart beat, and in rare instances, heart attack, stroke or death. Every effort will be made to minimize these risks by evaluation of preliminary information relating to you health and fitness and by observations during the test. Emergency equipment and trained personnel are available to deal with unusual situations that may arise.

3. Responsibilities of the Participant

Information you possess about your health status or previous experiences of unusual feelings with physical effort may affect the safety and value of your exercise test. Your prompt reporting of feelings with effort during the exercise test itself are also of great importance. You are responsible to fully disclose such information when requested by the testing staff.

4. Benefits To Be Expected

The results obtained from the exercise test may assist in diagnosis of your illness or in evaluating what type of physical activities you might do with low risk of harm.

5. Inquiries/ Confidentiality

Any questions about the procedures used in the exercise test or in the estimation of functional capacity are encouraged. If you have any doubts or questions, please ask us for further explanations. If questions should arise after leaving the test, please call Frank Micale (274- 1685/ 1301). Please be assured upon completion of the test your individual results of the test will be treated with the strict confidence given to all medical records. Your data may, however, may be averaged in with others for group reporting which preserves your confidentiality.

6. Freedom of Consent

Your permission to perform this exercise test is voluntary. You are free to deny consent or stop the test at any point, if you so desire.

I have read this form and I understand that the test procedures that I will perform. I consent to participate in the test.

Date ____________________ Signature of Participant ____________________

Date ____________________ Signature of Witness ____________________

Date ____________________ Signature of Tester ____________________

APPENDIX D

24-Hour History

NAME: ________________ DATE: ___________________

TIME: ________________

HOW MUCH SLEEP DID YOU GET LAST NIGHT? (Please circle one)
1 2 3 4 5 6 7 8 9 10 (hours)

HOW MUCH SLEEP DO YOU NORMALLY GET? (Please circle one)
1 2 3 4 5 6 7 8 9 10 (hours)

HOW LONG HAS IT BEEN SINCE YOUR LAST MEAL OR SNACK? (Please circle)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 (hours)

LIST THE ITEMS EATEN: ____

____

WHEN DID YOU LAST:

Have a cup of coffee or tea ________________

Smoke a cigarette, cigar, or pipe ________________

Take drugs (including aspirin) ________________

Drink alcohol ________________

Give blood ________________

Have an illness ________________

Suffer from respiratory problems ________________

WHAT SORT OF PHYSICAL ACTIVITY DID YOU PERFORM YESTERDAY?

WHAT SORT OF PHYSICAL ACTIVITY DID YOU PERFORM TODAY?

DESCRIBE YOUR GENERAL FEELINGS BY CHECKING ONE OF THE FOLLOWING:

________ Excellent

________ Very, Very Good

________ Very Good

________ Neither Good nor Bad

________ Bad

________ Very Bad

________ Very, Very Bad

________ Terrible

APPENDIX E

IDNO: ______

IC- IFD Data Collection Sheet

NAME: ______________________ DATE: ______________________

AGE: ______________________ TIME: ______________________

HEIGHT: _____ (inches) = _____ (centimeters)

WEIGHT: ______ (lbs.) = ______ (kg)

Station #1:

Informed Consent: _____ (check when completed)

Warm – up (5-min on cycle): ______ (check when completed)

Station # 2:

Stair Climb:

Weight (with 50- lb. vest and fire protective gear): _________ lbs
**(also used as stepping resistance on Manual program)

Time completed: __________ Speed: ________

Warm -up: ________ (20 seconds)

Test: ______ (3:00 at 60 spm) RPE at 1:30 _____ RPE at 3:00 _____

Number of touches to handrails: ________

Victim Rescue:

Total Distance: ________ (100 feet)

Time completed: ________ (seconds)

Number of rests: ________

Number of readjustments: ________

Lifting Technique: _______

1= Very poor~ does not use legs, excessive torso flexion
2=
3= Good~ flexed hips and knees, but torso is too flexed
4=
5= Very good~ uses knees and hips to lift and support back